

Time-Resolved Backside Probing of Femtosecond-Laser-Pulse-Produced Plasmas in Transparent Solids

B.-T. V. Vu and R. W. Lee
Lawrence Livermore National Laboratory
L-015, P.O. Box 808
Livermore, CA 94550

ABSTRACT

A plasma is created by $3 \times 10^{15} \text{ W/cm}^2$ intensity, 210fs laser pulse irradiation of a transparent solid target overcoated with carbon films of variable thickness. From time-resolved backside reflectivity, we infer the characteristic times for the important energy transport mechanisms.

Summary

We report on time-resolved femtosecond optical backside probe measurements of high temperature and solid density plasmas. The plasma is produced by irradiation of a transparent fused quartz target with 210fs FWHM, $\lambda = 810 \text{ nm}$ (pump) laser pulses at a peak intensity $3 \times 10^{15} \text{ W/cm}^2$. The plasma is probed by a non-perturbative, 210fs duration pulse. The probe pulse is incident from the rear side of the target to interact with the solid density plasma and cold solid interface region. The target is 1.6mm thick, and is coated at the front surface with a absorptive amorphous carbon film. The absorptive carbon film is to enhance absorption and localize laser energy deposition delivered by the pump pulse at the surface. This thus sets up a high temperature heat source at the surface for

subsequent generation and propagation of an electron thermal transport driven heat wave into the bulk region. The rear surface of the target is also coated with an anti-reflection film to suppress reflection from that surface. Reflection of the backside probe light is monitored as a function of relative time delay between the pump and probe pulses. These time-resolved reflectivity measurements, which are an indicator of the plasma temperature and density resulting from electron thermal transport and plasma expansion, are also taken for targets with carbon films as thick as 2100\AA .

Figure 1(a) shows a scan of the probe reflection as a function of time delay for targets overcoated with a 300\AA carbon film. Each data point is a measurement with a single laser shot. The data during negative delay, when the probe arrives prior to, and sees the targets undisturbed by the pump, correspond to the values for cold targets. At later delay, the probe reflection is strongly enhanced. This enhancement is due to a steep gradient thermal wave supersonically moving into the bulk region. Following the enhancement is the slow decrease due to increasing absorption by the plasma that is gradually cooled by relaxation of the thermal wave and slow plasma expansion into the vacuum region at the front side. Figures 1(b-f) display the data taken in the same experimental conditions for targets overcoated with thicker carbon films. All the data indicate a strong and fast reflection increase and a slow decrease. Figure 2 shows the extracted values of maximum reflectivity as a function of the carbon thickness. Figure 2 also plots the maximum reflectivity occurrence time, suggesting a transition from a supersonic heat wave regime, where the plasma is predominantly heated by a thermal wave, to a subsonic or ablative wave regime where the thermal wave is preceded by a shock

wave resulting from plasma expansion. The measurements, indicating the possibility to keep track of the fast thermal and shock waves that induce the reflectivity enhancements, will be discussed in greater detail to infer importance of electron thermal transport and plasma expansion.

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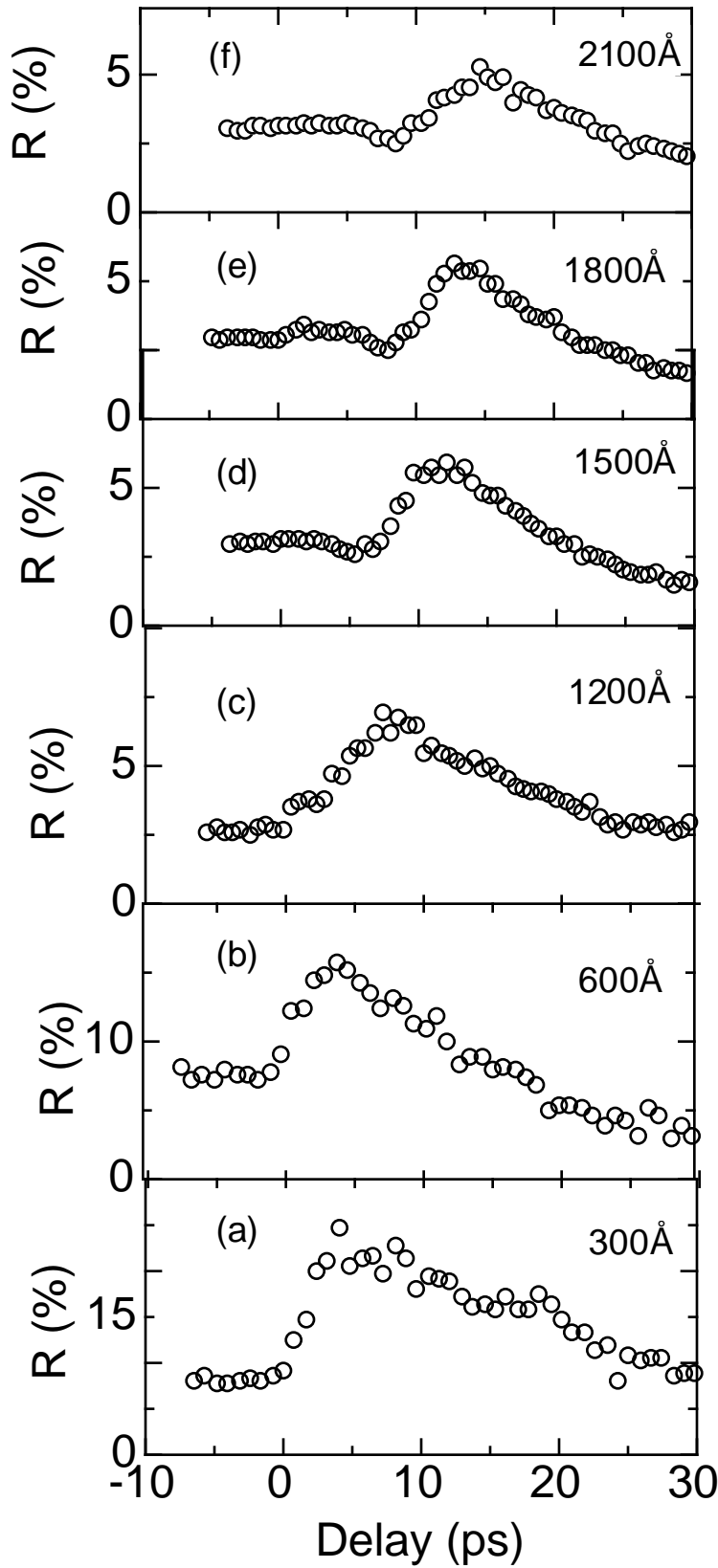


Fig.1: Time-resolved reflectivity of the plasma by backside probing for targets overcoated with carbon films of different thicknesses is measured as a function of time delay between the pump and probe pulses.

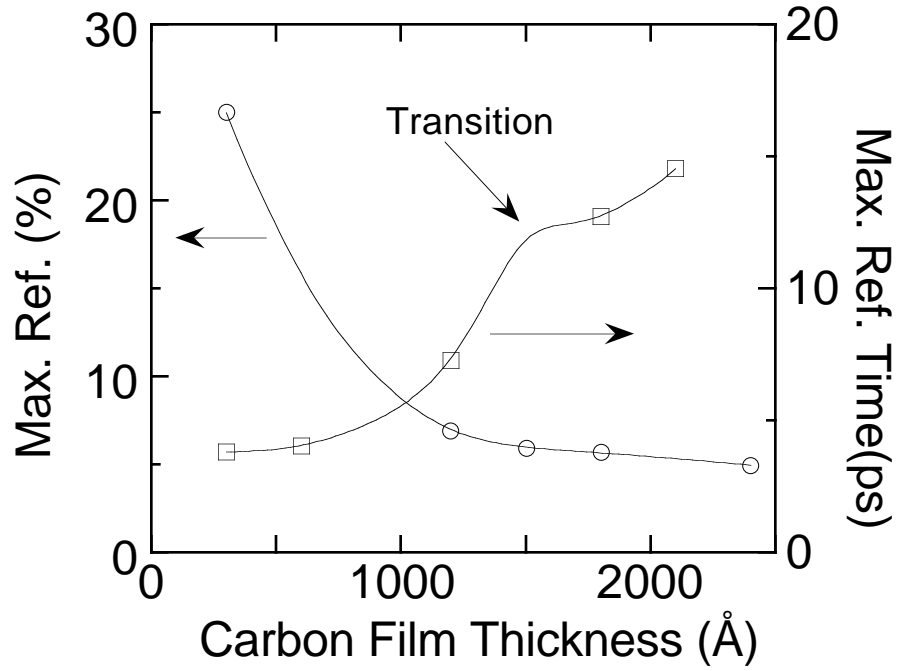


Fig.2: Extracted values of plasma maximum reflectivity (circles) and its occurrence time (squares) are plotted as functions of the carbon film thickness. The kink at $\sim 1500\text{\AA}$ suggests a transition from supersonic heat wave regime to subsonic or ablative wave regime.